Environmentally Responsible Aviation Project
Status of Airframe Technology Subproject
Integrated Technology Demonstrations

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Outline

- ERA Project Goals and Research Themes
- Airframe Technology Subproject Integrated Technology Demonstrations
  - Damage Arresting Composites Demonstration
  - Adaptive Compliant Trailing Edge Flight Experiment
- Concluding Remarks

ERA Project Goals and Research Themes

Mature technologies and study vehicle concepts that together can simultaneously meet the NASA Subsonic Transport System Level Metrics for noise, emissions, and fuel burn in the N+2 timeframe

-75% LTO & -70% Cruise NOx Emissions	42dB below Stage 4 Community Noise	-50% Aircraft Fuel/ Energy Consumption

Research Themes

Accelerate technology maturation through integrated system research

Innovative Flow Control Concepts for Drag Reduction	Advanced Composites for Weight Reduction	Advanced UHB Engines for SFC & Noise Reduction	Advanced Combustors for Oxides of Nitrogen reductions	Airframe & Engine Integration for Community Noise Reduction

ERA Project
Research Themes and Technical Challenges

TC1 **Innovative Flow Control Concepts for Drag Reduction**

- Demonstrate drag reduction of 8 percent, contributing to the 50 percent fuel burn reduction goal at the aircraft system level, without significant penalties in weight, noise, or operational complexity

TC2 **Advanced Composites for Weight Reduction**

- Demonstrate weight reduction of 10 percent compared to SOA composites, contributing to the 50 percent fuel burn reduction goal at the aircraft system level, while enabling lower drag airframes and maintaining safety margins at the aircraft system level

TC3 **Advanced UHB Engine Designs for Specific Fuel Consumption and Noise Reduction**

- Demonstrate UHB efficiency improvements to achieve 15% TSFC reduction, contributing to the 50 percent fuel burn reduction goal at the aircraft system level, while reducing engine system noise and minimizing weight, drag, NOx, and integration penalties at AC system level

TC4 **Advanced Combustor Designs for Oxides of Nitrogen Reduction**

- Demonstrate reductions of LTO NOx by 75 percent from CAEP6 and cruise NOx by 70 percent while minimizing the impact on fuel burn at the aircraft system level, without penalties in stability and durability of the engine system

TC5 **Airframe and Engine Integration Concepts for Community Noise and Fuel Burn Reduction**

- Demonstrate reduced component noise signatures leading to 42 EPNdB to Stage 4 noise margin for the aircraft system while minimizing weight and integration penalties to enable 50 percent fuel burn reduction at the aircraft system level

Damage Arresting Composites Demonstration

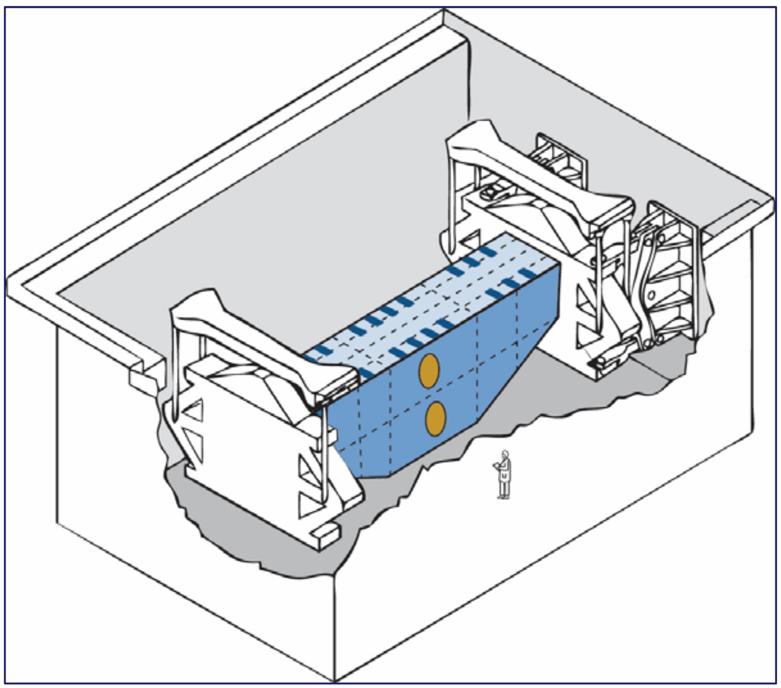
Damage Arresting Composites Demonstration
NASA and Boeing Partnership

NASA LaRC

- ERA Project Management
- Resources
- Technology Objectives, Requirements
- Building Block Approach
- Analysis
- COLTS Facility Management and Testing

Boeing

- Technology Objectives, Requirements
- Design and Analysis
- Building Block Approach
- MBB Fabrication



Damage Arresting Composite Demonstration Overall Approach – Technology Maturation

Weight | Drag | TSFC | Noise | NOx

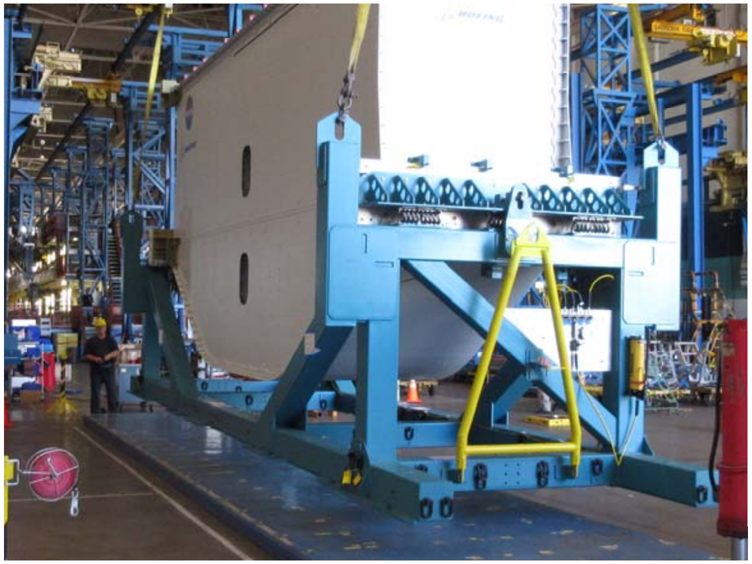
End TRL: 5

Key Performance Parameter Goal

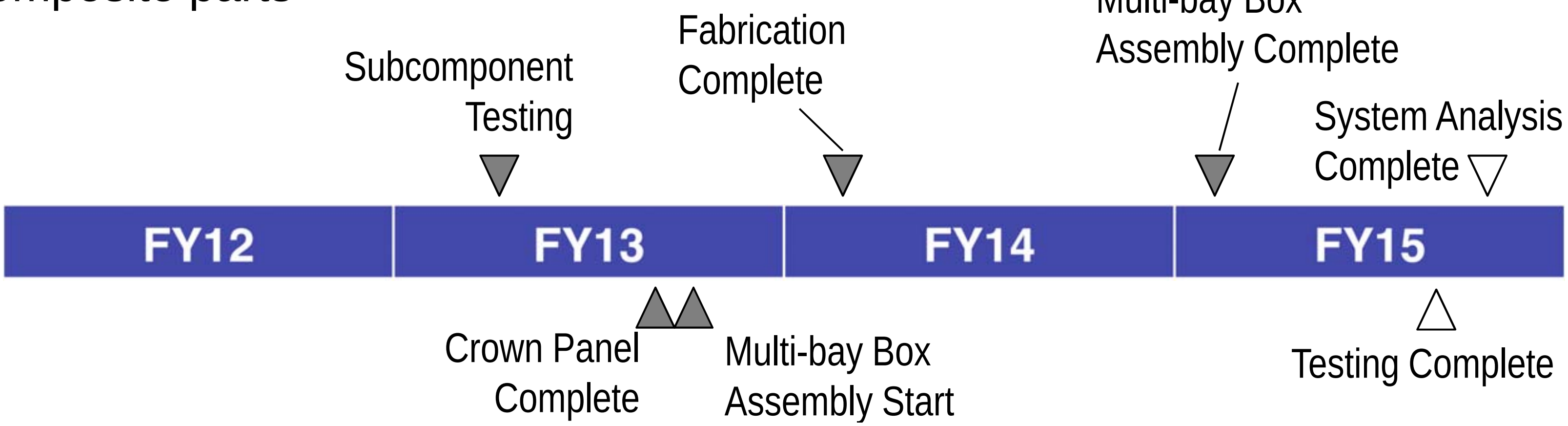
Reduce structural weight by 20% for LTA Class Aircraft with GTF Engine

Technology Insertion Challenges Addressed

- Damage tolerance
- Post-buckled composite structure
- Integrated system weight
- Large-scale, light-weight, infused composite parts

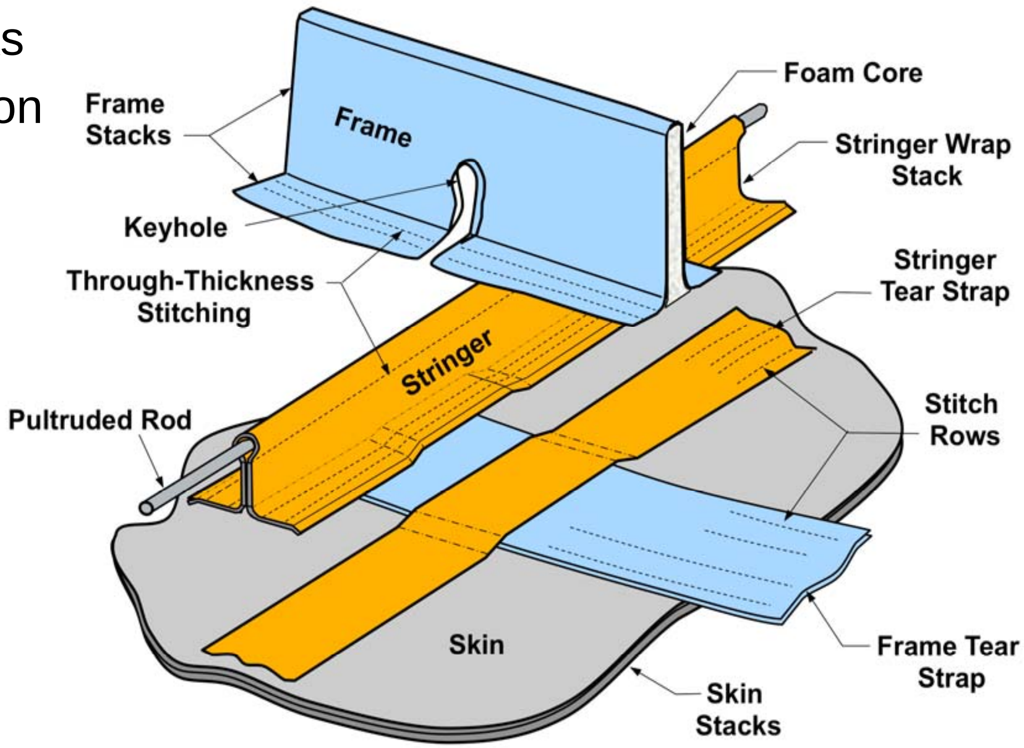


Assembled Multi-bay Box in C-17 Factory



Damage Arresting Composites Demonstration – Benefits of Pultruded Rod Stitched Efficient Unitized Structure (PRSEUS)

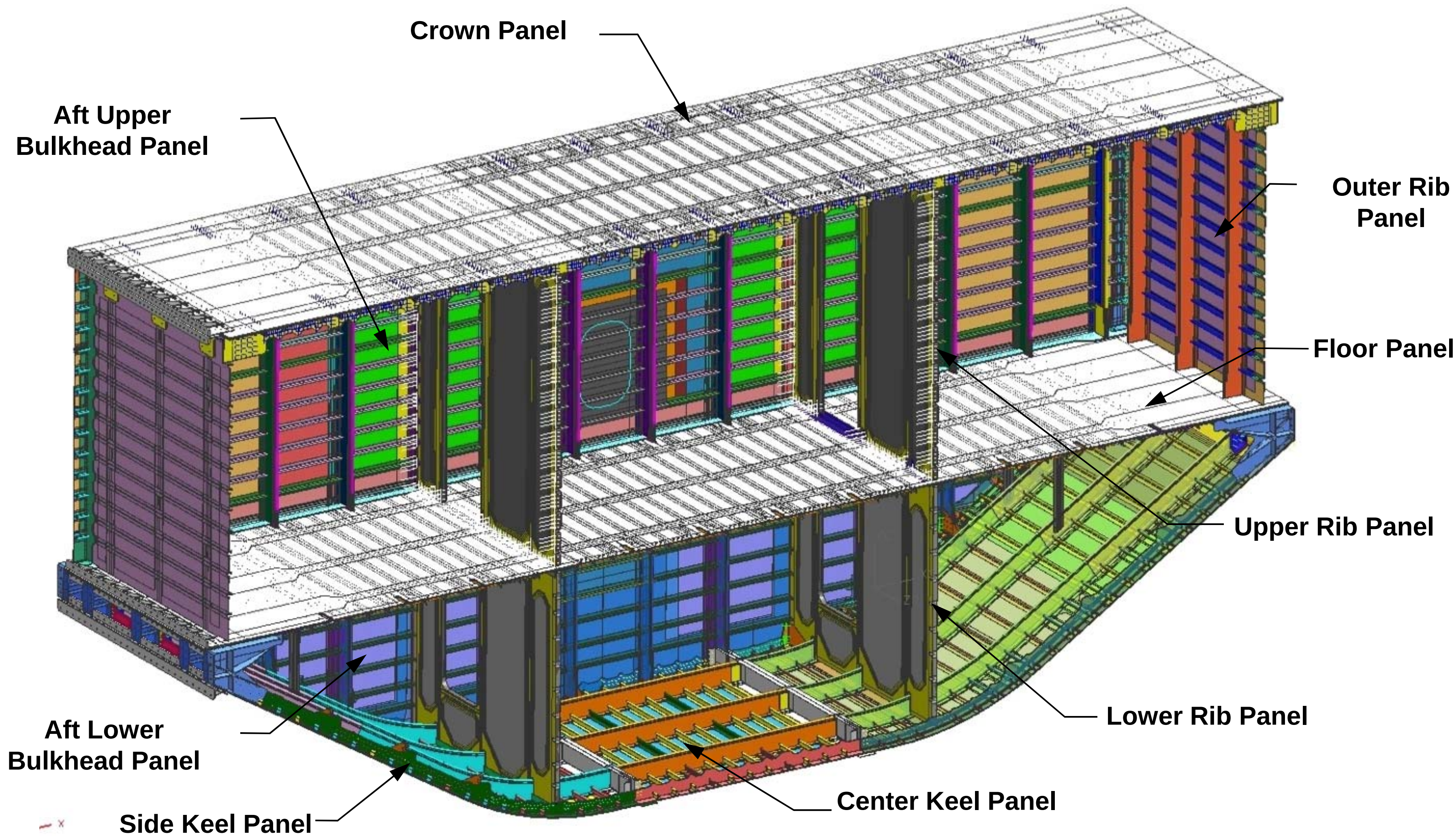
- Eliminates fasteners in acreage
  - No holes to start cracks or to inspect
  - Reduced part count
  - Reduced final assembly time
- Allows for all composite elements in very large parts to be simultaneously cured (stiffeners, clips, skin, doublers, etc.)
- Stitching arrests and turns cracks
- Stitching suppresses delamination
- Allows extensive use of post-buckling
- Changes the design philosophy which opens the design space



Exploded View of Preform Assembly

Damage Arresting Composites Demonstration Multi-Bay Box Layout

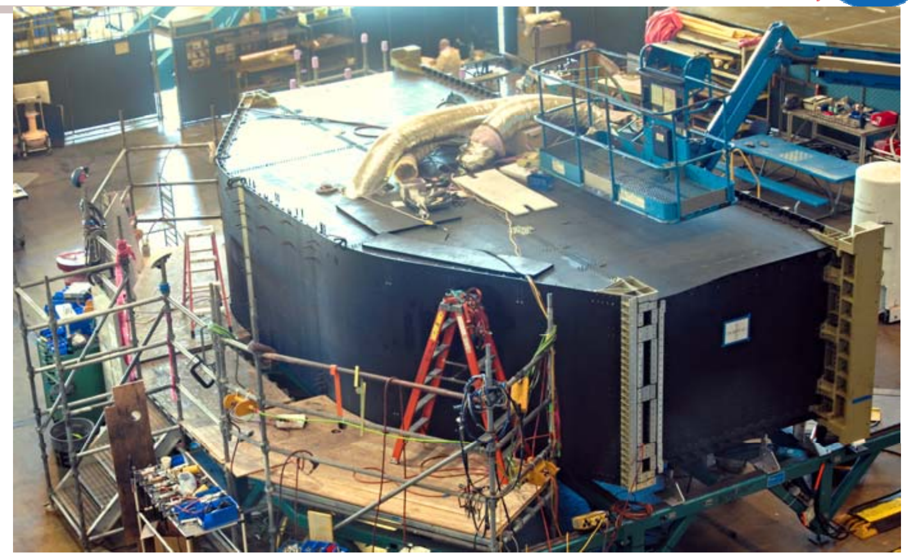
Multi-Bay Box: 7'D X 30'L X 13' H   11 PRSEUS Panels; 4 Sandwich Panels



<u>Note</u>: Fwd Bulkhead Panels Removed for Clarity

Damage Arresting Composites Demonstration Multi-Bay Box Assembly At Long Beach C-17 Facility

June 2013
Upper panels positioned for fit up but not fastened



July 2014
Upper complete; working on lower

October 2014
MBB complete, rotated and placed on transportation fixture

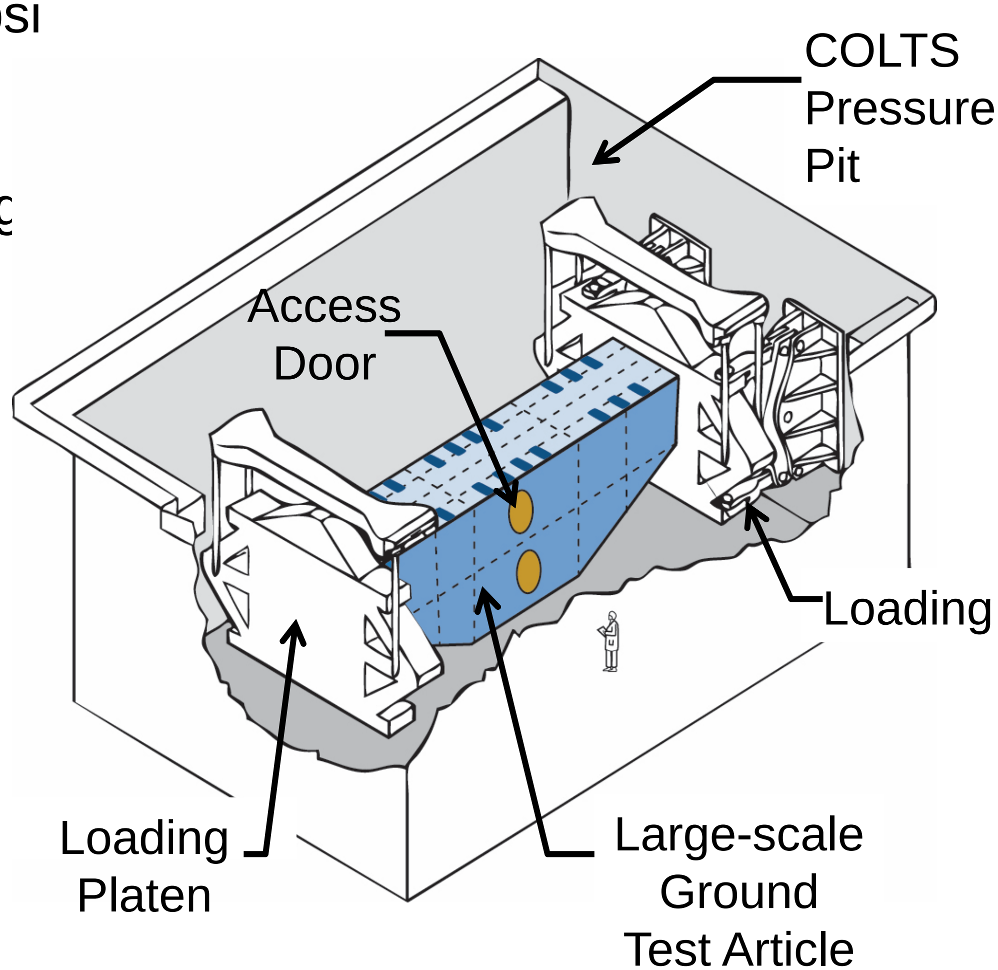
Damage Arresting Composites Demonstration Combined Loads Test Facility (COLTS), NASA-LaRC

MBB Testing Conditions

- Internal pressure alone to 18.4 psi
- 2.5 G Up-bending to DUL
- 1G Down-bending to DUL
- Combined Pressure and Bending
- Barely Visible Impact Damage

MBB Test Will Demonstrate

- Damage arrestment
- Pristine structure sustains DUL in five load cases
- Supports DUL even with Barely Visible Impact Damage
- Test-analysis correlation



Damage Arresting Composites Demonstration Future Work

- Installation of MBB into COLTS facility
- Post-Delivery Test Readiness Review at LaRC – April 2015
- Continue nonlinear analysis supporting failure predictions
- Testing – Applying 5 loading conditions in a series of 20 tests including both a pristine and damaged structure
- Post-test evaluation
- System study to roll up findings from experiment to aircraft studies

Adaptive Control Trailing Edge (ACTE) Flight Experiment

ACTE Flight Experiment
NASA and AFRL Partnership

NASA LaRC
- Resources (ISRP Program)
- ERA project management
- Research objectives, requirements

NASA AFRC
- ACTE ITD management
- Research engineering
- Aircraft modifications
- Instrumentation
- Airworthiness

NASA ARC
CFD analysis

AFRL
- Flap development management
- Research objectives, requirements

FlexSys
- Design
- Instrumentation requirements

ACTE Flight Experiment
Overall Approach – Technology Maturation

Weight | Drag | TSFC | Noise | NOx | **End TRL: 6**

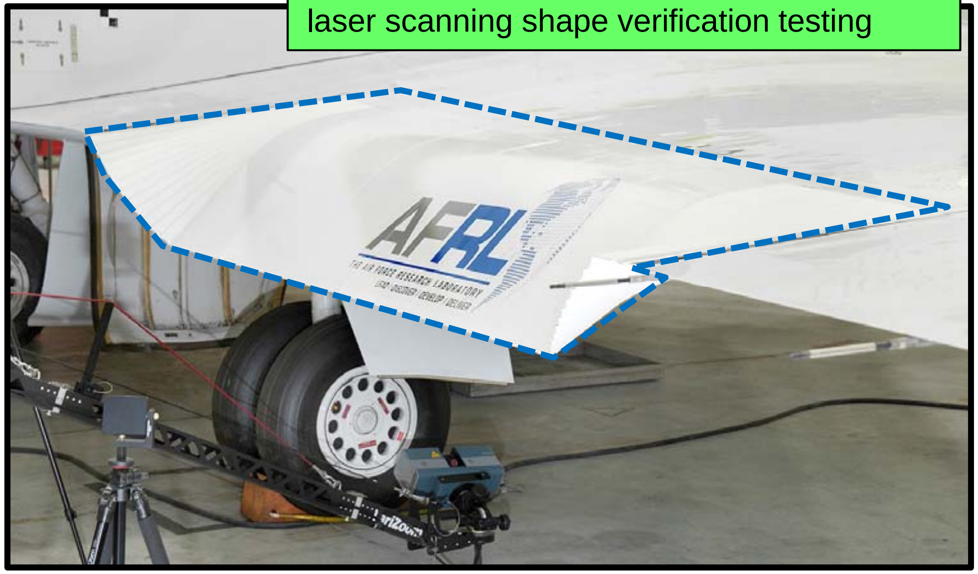
Key Performance Parameter Goal

Demonstrate in flight the viability of an ACTE system, to enable a 5% reduction in wing weight when using a MLC / GLA system on transport aircraft

Technology Insertion Challenges to be Addressed

- Airworthy, non-metallic compliant trailing edge flown at high dynamic pressures
- Flexible transition region flown at transonic high altitude flight conditions
- Analytical and ground test flutter predictions validated through flight

Right side ACTE on G-III wing undergoing laser scanning shape verification testing



G-III Phase 0A Check-Out Flights Complete

Flap Delivery

G-III Phase 0B Flights Complete

Flight Test Complete

System Analysis Complete

FY12 | FY13 | FY14 | FY15

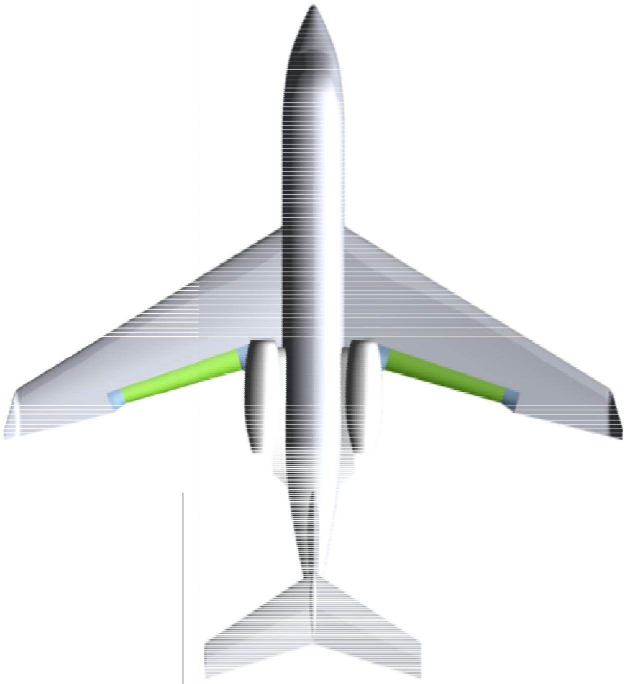
ACTE CDR

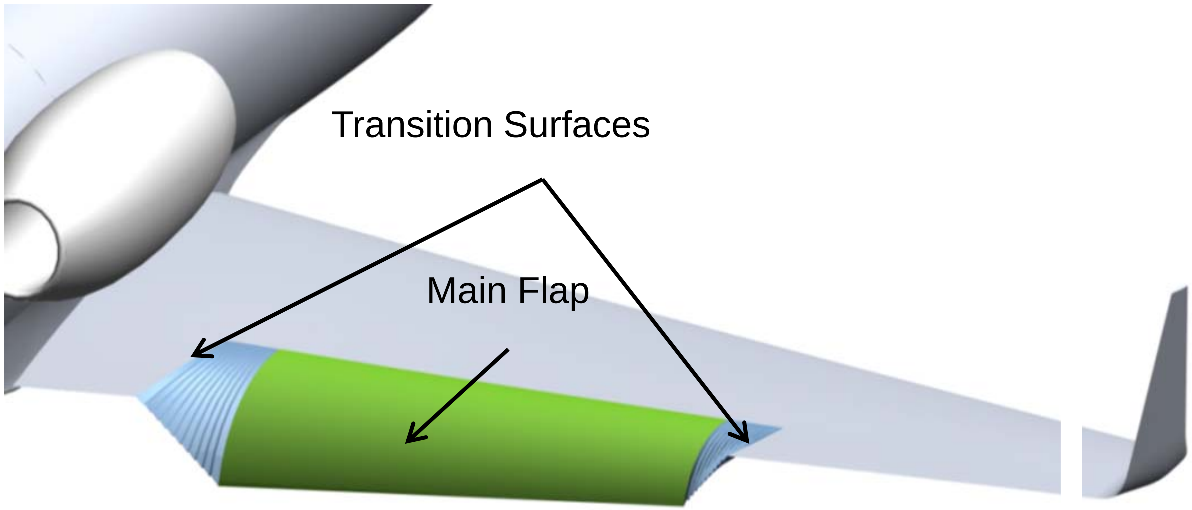
Instrumented Flap Cartridge Complete

G-III De-modification Complete

ACTE Flight Experiment
ACTE Benefits

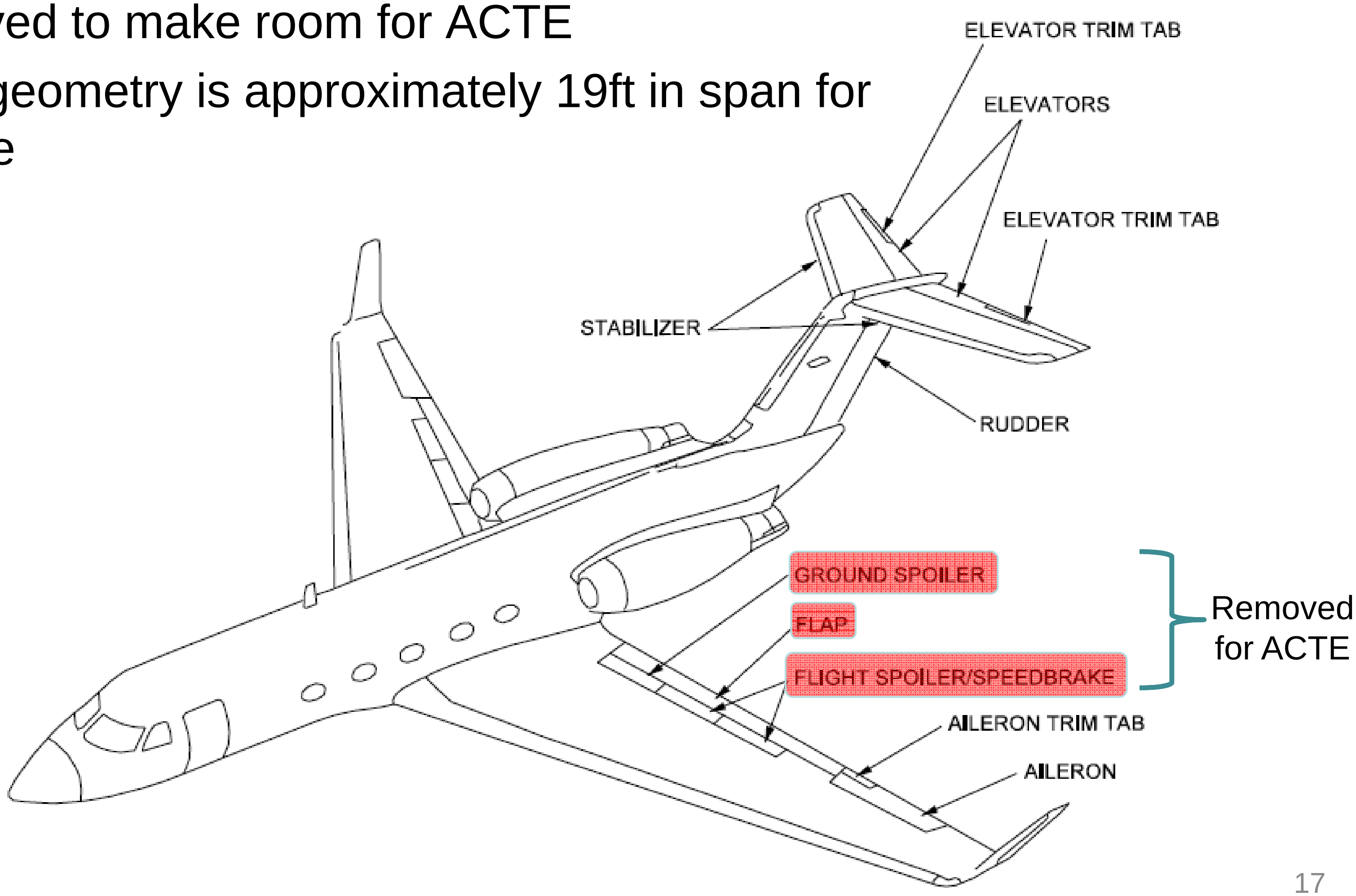
- Predicted adaptive compliant technology performance benefits include:
  - Cruise trim drag reduction
  - Span-wise twist to reduce induced drag
  - Load alleviation resulting in weight reduction
  - Increased control surface effectiveness





ACTE Flight Experiment
Flap Replacement

- Compliant flap replacing both aircraft flaps in their entirety
- Ground Spoilers, Flight Spoilers / Speedbrakes and Flaps removed to make room for ACTE
- Target flap geometry is approximately 19ft in span for each surface



ACTE Flight Experiment
Flap Installation on G-III Aircraft

Left ACTE Cartridge being integrated into the G-III wing cove.

Right ACTE Cartridge integrated into the G-III wing cove.

ACTE Flight Experiment

- Demonstrate through flight testing a range of ACTE flap deflections within the G-III flight envelope up to Mach .75
  - -2° (up) to +30° (down) at low speeds
  - -2° to +5° over the entire envelope
  - No in-flight actuation
- Collect in-flight structural and aerodynamic data to support analysis verification
- High rate deflections & fatigue will be done on the ground
- ACTE envelope clearance flights will capture desired test points

ACTE Flight Experiment
ACTE Ground Unit Under Test

- 3200 Large Flap Deflections…and counting

ACTE Flight Experiment
Future Work

- Complete flight testing of -2° to +30° flap deflections
- Post-test evaluation
- System study to roll up findings from experiment to aircraft studies
- De-modification of the G-III aircraft

Concluding Remarks

- Damage Arresting Composites Demonstration Multi-Bay Box is complete and being prepared for COLTS testing, and is on track to meet technical objectives

- ACTE Flight Experiment has begun with 0° and +2° flap deflections, and is on track to meet technical objectives